REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
25 September 1996

3. REPORT TYPE AND DATES COVERED
Technical

4. TITLE AND SUBTITLE
Innovative Approaches to Watershed Characterization: Winters Run Watershed Pilot Project - A Case Study

5. FUNDING NUMBERS
N/A

6. AUTHOR(S)
National Institute for Environmental Renewal's Industry Team

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Institute for Environmental Renewal
(NIER)

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

SERDP
901 North Stuart St. Suite 303
Arlington, VA 22203

Waterways Experiment Station
US Army Corps of Engineers

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES
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12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 Words)*

Winters Run serves as a primary drinking water source for the town of Belair and for the Edgeweed section of Aberdeen Proving Ground (APG). The purpose of this study was to apply and assess the capabilities of the prototype EMMS at a military facility designated by Waterways Experiment Station. The Department of the Army owns Atkisson Reservoir and the VanBibber Water Treatment Plant, both of which reside in the southern portion of this watershed. Atkisson dam was built by the Army in 1942 to ensure an adequate flow of potable water to the Edgewood portion of APG by supplementing low flows in Winters Run. The APG Environmental Installation staff selected Winters Run watershed as candidate site for this pilot project.

The objectives of the pilot project were to: understand subcatchment soil loss and sediment transport dynamics; quantify impacts to water quality from subcatchment loadings; determine impacts from wet-weather events during the Spring '96 runoff period; investigate watershed landuse changes and their relative impact upon hydrology; provide the necessary technical analysis to support an upcoming NEPA EIS concerning possible remedial actions at Atkisson dam.

The project also had the objectives of advancing the integration methodology of GIS technology with water-quality modeling software and demonstrating the value of the EMMS' architecture and functionality.

14. SUBJECT TERMS
watershed characterization
GIS SERDP
water quality modeling SERDP Collection

15. NUMBER OF PAGES
36

16. PRICE CODE N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclass.	unclass.	unclass.	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

Innovative Approaches to Watershed Characterization: Winters Run Watershed Pilot Project — A Case Study

Prepared for:

Strategic Environmental Research and Development Program (SERDP)

and

Army Corps of Engineers, Waterways Experiment Station (WES)

Prepared by:

National Institute of Environmenal Renewal (NIER)

and

PAR Government Systems Corporation

25 September 1996

Abstract

This project was funded under a research grant, contract number 818-94 (Task 2), from the Strategic Environmental Research and Development Program. The work was performed by National Institute for Environmental Renewal's Industry team. The primary purpose of this effort was to serve as a technology demonstration of the Environmental Monitoring and Management System (EMMS) at a military facility designated by the project technical consultant, U.S. Army Corps of Engineers Waterways Experiment Station, and the DOD installation environmental project staff. This demonstration provided the opportunity to show how the EMMS could support environmental problem solving and common resource problems faced by DOD natural resource/conservation managers. The selected study area - the Winters Run watershed - serves as a primary drinking water source for the U.S. Army's Aberdeen Proving Ground (APG)- Edgewood area. This watershed is subject to severe soil loss in selected subcatchments, agricultural/rural runoff contributions, as well as significant degradation of water quality due to apparent stormwater outfall discharges. This work will support an upcoming EIS study to address projected changes in the structure of the U.S. Army-owned Atkisson dam, which also resides in this watershed.

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1. INTRODUCTION

Under a Strategic Environmental Research and Development Program (SERDP) natural resources and conservation grant, the Environmental Monitoring and Management System (EMMS) was deployed to assess the Winters Run watershed in Harford County, MD. EMMS incorporates state-of-the-art data management and visualization methodologies regarding data integration/fusion, imagery exploitation, modeling and sensor-based monitoring and spatial data analysis. The prototype EMMS uses ARC/INFO and ARCVIEW GIS software, (ESRI, Inc., Redlands, CA), as the primary integration tool, and customized AVENUE, (ESRI, Inc.), scripting to generate simulation data sets and to conduct spatial/temporal animations of modeling scenarios.

Winters Run serves as a primary drinking water source for the town of Belair and for the Edgewood section of Aberdeen Proving Ground (APG). The purpose of this study was to apply and assess the capabilities of the prototype EMMS at a military facility designated by Waterways Experiment Station (WES). The Department of the Army owns Atkisson Reservoir and the VanBibber Water Treatment Plant, both of which reside in the southern portion of this watershed. Atkisson dam was built by the Army in 1942 to ensure an adequate flow of potable water to the Edgewood portion of APG by supplementing low flows in Winters Run—as water is drawn—at Van Bibber Water Treatment Plant. The APG Environmental Installation staff (in cooperation with WES) selected Winters Run watershed as the candidate site for this pilot project.

The objectives of the pilot project were to:

1) understand subcatchment soil loss and sediment transport dynamics;
2) quantify impacts to water quality from subcatchment loadings;
3) determine impacts from wet-weather events during the Spring '96 runoff period;
4) investigate watershed landuse changes and their relative impact upon hydrology;
5) provide the necessary technical analysis to support an upcoming NEPA EIS concerning possible remedial actions at Atkisson dam.

The project also had the general objectives of advancing the integration methodology of GIS technology with water-quality modeling software and demonstrating the value of the EMMS' architecture and functionality.

2. STUDY AREA

The Winters Run watershed is approximately 60 square miles, and is located in the west-central region of Harford County. This watershed containing areas of forests and agricultural land has experienced substantial cultural development over the past 20 years. The geomorphology of the main river channel is characterized by a relatively narrow valley

and steep banks along the main channel. The prevailing humid, continental climate is accompanied by strong weathering and leaching of the soils. Soil loss contributions are apparent along the entire reach of Winters Run, as evidenced by the formation of numerous sand bars and islands that have significantly altered the stream's course.

The two predominant soil groups of the area consist of Manor and Glenelg series. Manor soils demonstrate moderate to moderately rapid permeability and are among the most susceptible to erosion and to the effects of common landuses—including farming. A coarse loam suitable for growing many common crops and for pastureland constitutes the steeper parts of the landscape (3–8% slopes), which are more easily eroded. The soils found on the gently rolling hills are the more stable Glenelg series (fine loam). These are deep, well-drained, gently sloping soils, and once again are well-suited to farming. The alluvial flood plain consists mostly of silts and clayey sand.

Winters Run provides an estimated flow of 3 million gallons per day for drinking water requirements. Major tributaries above Atkisson dam include: East and West Branches, Plumtree Run, Heavenly Waters, Long Branch, Elbow Brook, Bear Cabin Branch, and Bread and Cheese Branch. Both Winters Run and Plumtree Run provide flow to Atkisson reservoir. Winters Run drains into Bush River via Otter Point Creek. These streams flow through substantial portions of cropland and residential areas, thus providing numerous potential sources of nonpoint source pollution. Field observations indicate that Winters Run transports large amounts of sediment accumulations at Atkisson Reservoir, at a small dam located at the American Water Water Treatment Plant, and above the weir at Van Bibber Water Treatment Facility.

The state of Maryland has divided Winters Run into two classes of water quality. Above Atkisson dam, the designated use is Class IV (recreational/trout waters); below the dam, Winters Run is classified as Class I (water contact for recreation and fishing). Maryland's current water-quality standards for Class I and Class IV waters include: turbidity < 50 NTU, dissolved oxygen > 5mg/l, and nitrates < 10 mg/l. Winters Run contains few NPDES-permitted point sources. These include car washes, a sand and gravel company, a closed landfill, and the water-treatment facilities mentioned above. Stormwater events presumably account for the majority of loadings in this watershed. Major stormwater outfalls exist at the Constant Friendship Shopping Center and Festival of Belair Shopping Center. In the past, Plum Tree Run has shown evidence of seepage from septic systems.

3. METHODOLOGY

3.1 DEVELOPMENT OF GIS DATABASE

During this project, various sets of spatial data were collected, converted and integrated. With the exception of the USGS topographic coverage of Harford County which was scanned, all of the spatial data existed in a digital form, made available by federal, state, or county sources. As such, the development of the GIS database was primarily a data conversion process, thereby providing substantial savings in terms of time and money. A metadata dictionary also was developed in accordance with the Federal Geographic Data

Committee standard, dated 24 March 95. In particular, watershed characterization was performed based upon the following five layers of raster data: digitized USGS topographic maps and digital elevation maps (DEMs), county digital terrain maps (DTMs), Fall 1995 LANDSAT-TM satellite imagery, and April 1996 aerial photography. Four vector source data coverages included: digital line graphs, USEPA's Reach RF3 file, NRCS Statsgo, and County DGNs, including roads/hydrology/soil files. Cross-sectional data were collected using both conventional field survey techniques and a global positioning system (GPS) device. Historical environmental contaminant data were obtained through the review of USEPA's STORET and PCS digital files, and from the Harford County Dept of Public Works outfall data.

These data were applied in the development of a three-dimensional terrain model for the purposes of watershed delineation. Classifications of landcover/landuse in the watershed were determined based upon a Fall 1995 LANDSAT-TM image. Based upon previously designated land classes from a 1975 land classification, a current landcover polygon coverage was created from a TIFF image using the PCI image analysis tool suite. This TIFF image was developed from a supervised classification using PCI. Aerial photography and orthophotography were used for training are definitions. As the table below indicates, the comparison revealed a significant decrease in the total amount of land classified as cropland and a corresponding increase in the amount of land classified as urban/developed.

Land Classification	1995 Imagery	1975 Imagery
Forest	48%	49%
Grassland (Pasture)	23%	26%
Farmland	7%	18%
Urban/Developed	21%	4%
Other (including water)	1%	3%

3.2 MODEL PARAMETER DETERMINATION

A suite of USEPA models was used to conduct the watershed characterization and dynamic (time series) modeling. A flow diagram of the modeling process is presented in Figure 1. Custom AVENUE scripts were used to automate the creation and calibration of input data sets. The hydrodynamic, riverine model (RIVMOD) was selected for dynamic flow routing. This model solves the one-dimensional, unsteady, St. Venant flow equations, based upon the laws of conservation of mass and momentum. The model required input data for channel geometry, hydraulic radius, depths, discharge, and Manning numbers. For purposes of channel definition, Winters Run was divided into quarter-mile

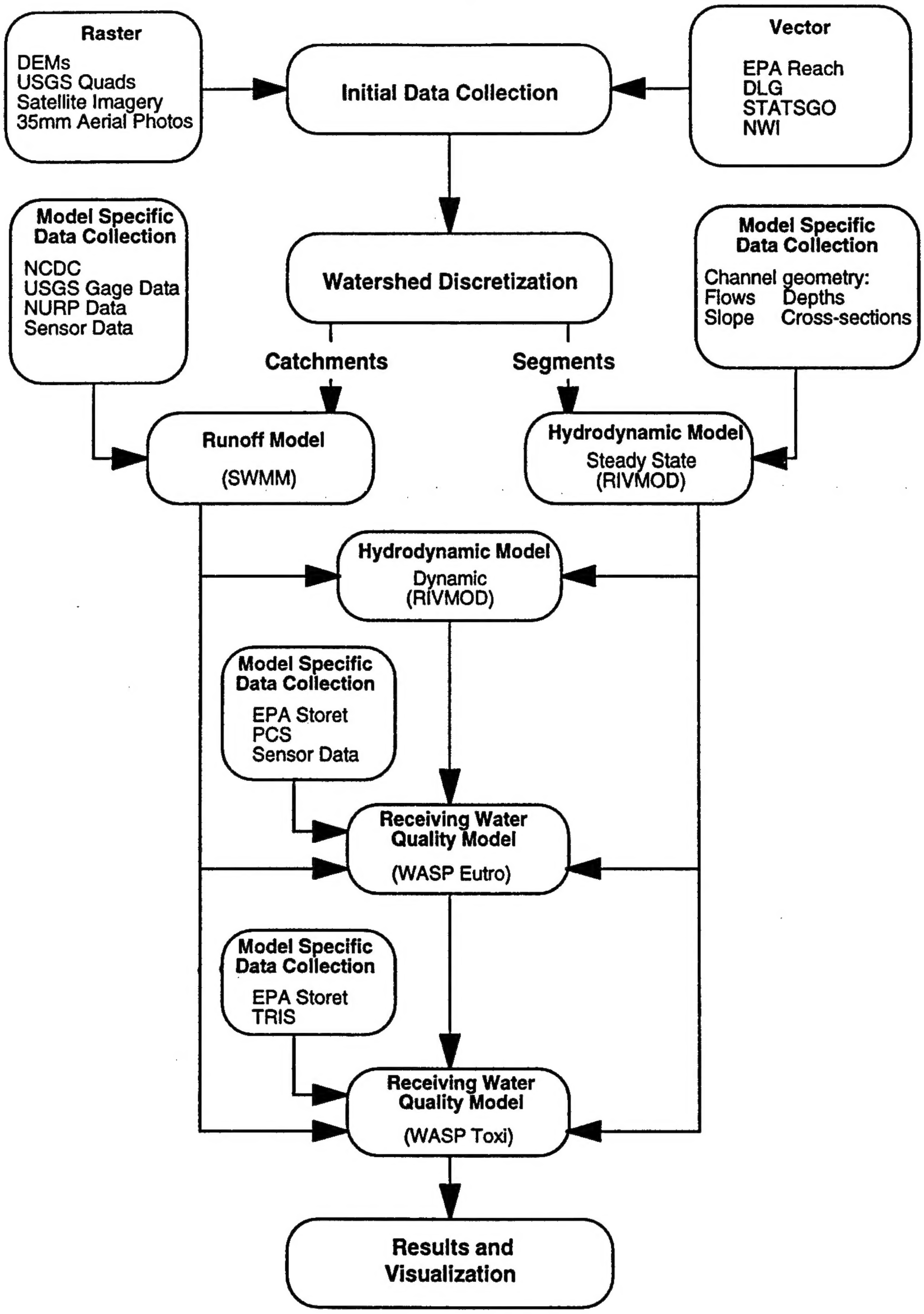

Figure 1. Process Flow

segments based on cross-sections that had been measured by a field survey team. A physical sediment survey was conducted, and a set of water chemistry grab samples was taken prior to commencement of the monitoring. The grab samples were sent for laboratory analysis and used for comparison against field sensor data. A second set of grab samples was obtained midway through the Spring runoff period to provide additional model calibration data. In addition, sediment oxygen demand was measured *in situ* via the use of benthic

chambers at selected sites along Winters Run. Measurements ranged from approximately 1.0 to 4.0 $gm^{-2}da^{-1}$ at the prevailing ambient temperature.

The field-surveyed cross-sections (widths and depths) varied from 18 ft^2 at the confluence of the East and West Branch to 276 ft^2 at Atkisson Reservoir. Similarly, elevations (above mean sea level) ranged from approximately 381 feet to 0.5 feet. In addition to topographic source data, a GPS device was used to precisely measure elevations. Channel slope was determined using changes in bottom elevations. Manning's equation was applied to compute Manning's coefficients for the channel. The maximum slope of the main channel exceeded 1.0% at the northernmost portion of the study area.

Due to the growing urbanization of the watershed, the Storm Water Management Model (SWMM) was selected for runoff modeling. This model allows for the simulation of nonpoint source, overland flow contributions to Winters Run — based on the definition of seven key "quantity" input parameters. In order to enable the production of individual hydrographs for each drainage basin, the SWMM requires segmentation of the watershed into discrete subcatchments (see Figure 2). These subcatchments were further defined by estimating overland flow path (based upon a defined subcatchment width) and average slopes. The percentage of land area determined to be pervious or imperviousness was estimated based upon the imagery-derived landuse/landcover classification. Manning roughness coefficients, "n" values, were estimated for overland and channel/tributary flow to Winters Run. Due to considerable diversity of ground cover types, overland flow manning numbers varied from 0.01 (for asphalt) to 0.40 (for grass/dense shrubs/forest litter). This range accounts for transitions between turbulent and laminar flow, and for the relatively small depths. Channel/tributary manning numbers ranged from 0.02-0.06. Soil survey estimates served as the basis for determining infiltration rates using Horton's equation. Minimum values ranged from 0.4 to 0.7 mm/hr and maximum values ranged from 1.8 to 3.8 mm/hr. Depression storage values ranged from 0.02 to 0.05 inches for impervious sources and measured at 0.25 inches for pervious sources.

In the "quality" portion of SWMM, pollutographs (constituent loadings) are generated for each subcatchment. Biochemical oxygen demand and nutrient contributions were simulated, and subcatchment soil loss was estimated. Average sheet erosion - soil loss from the individual subcatchments was determined using the ARS Universal Soil Loss Equation (USLE). The amount of channel erosion - soil loss which could be attributed solely to Winters Run was not measured. However, based upon field observations made during the sensor calibration activities, channel form and integrity was maintained throughout the spring runoff period. Based upon the Harford County soil survey and Maryland DNR information, the following equation factors were used:

1) soil (K) factor: average - 0.21, with a range 0.15 - 0.28

2) crop factor: average - 0.07, with a range of 0.04 - 0.10

3) control practice factor: average - 0.08, with a range of 0.01-0.23.

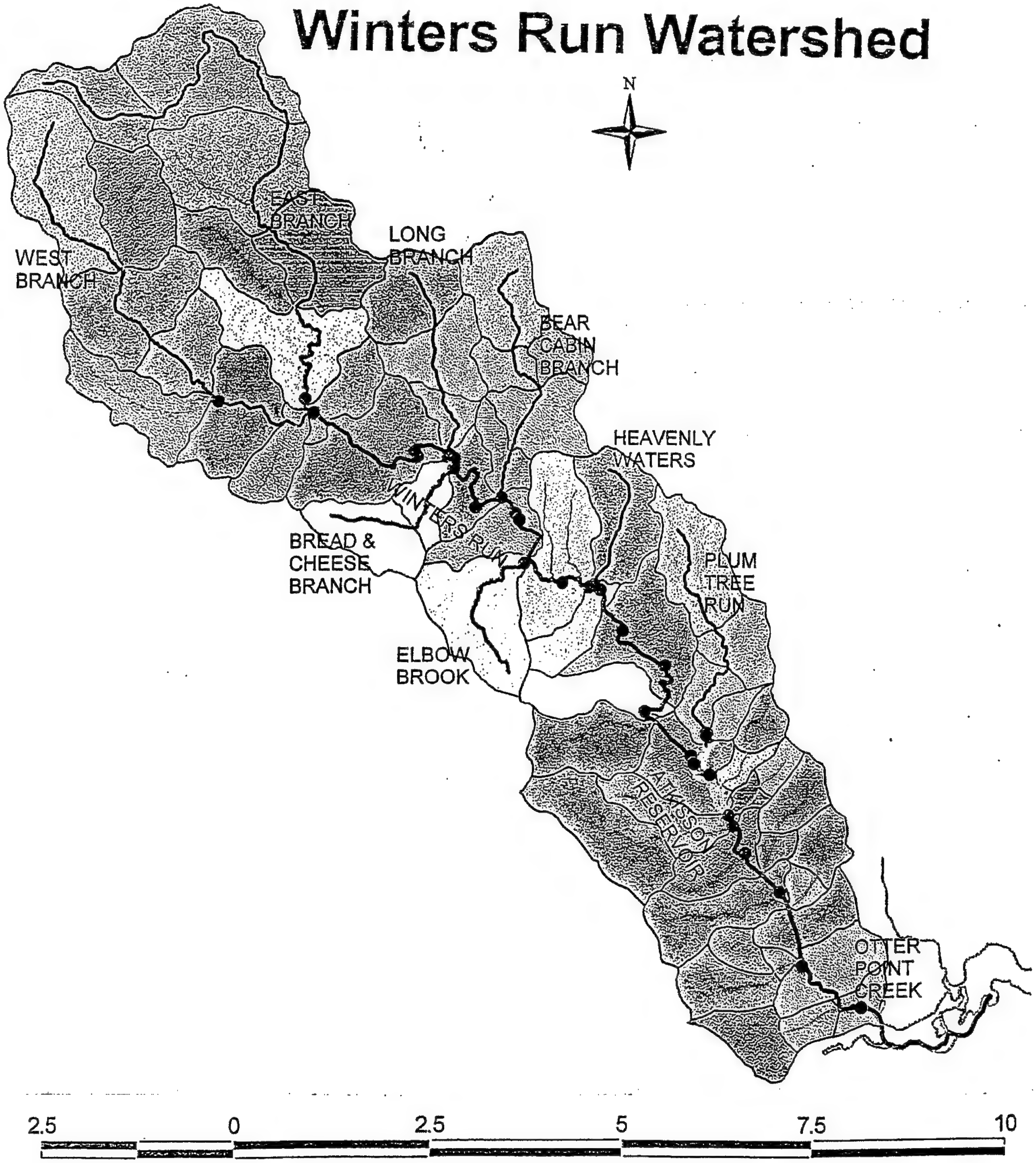

Figure 2. Definition of Individual Subcatchments

The Water Quality Analysis Simulation Program (WASP) was selected as the receiving water quality model. The Eutrophication (EUTRO) portion of the model simulates the advective/dispersive mass transport process related to key water quality variables. The channel definition (mentioned previously) was used for describing the channel geometry for the water quality modeling efforts. For this reason, the model was segmented based upon a one-to-one mapping with the linked hydrodynamic model. Moreover, the water quality model required that initial loads be specified for a variety of nutrients — including organic and inorganic forms of nitrogen and phosphorous, as well as for biochemical and chemical oxygen demand. These loadings were based upon field sampling and past historical records.

Sediment transport was modeled as a part of the receiving water quality model, specifically, the TOXI portion of WASP. For this analysis, sediment concentrations varied in response to changes in the net flux of sediment. This flux was based upon associated densities and Stokes' settling velocities established for clay, silt, and sand particles. Estimated subcatchment soil loss contributions were simulated by the runoff model, and were subsequently linked with surface

water lateral flows from the hydrodynamic model. Consequently, the model predicted changes in sediment bedload in Winters Run due to runoff contributions from the surrounding watershed.

3.3 FIELD SENSORS

Automated field sensor stations were deployed at pre-defined key locations along Winters Run. These stations incorporated telemetry, thereby allowing for daily data retrieval, analysis, and databasing at the NIER Operations Center in Pennsylvania. Two stage/water surface height (m) sensor stations were deployed — one upstream and one downstream of Atkisson Reservoir. In addition, a meteorological station was set up near Atkisson. Its components included a rain gage (mm), humidity (%), pressure (mbars), wind speed direction (m/s), and solar radiance (langleys) sensors. Five water-quality stations were installed. Each station consisted of one data logger, two sensor probes (deployed upstream and downstream of the data logger) for measuring dissolved oxygen (mg/l), temperature (degrees C), pH, conductivity (uS), turbidity (NTU), and open channel velocity (m/s), and ion-specific electrodes for measuring nitrates (mg/l) and ammonium (mg/l). These stations were calibrated, at a minimum, on a weekly basis for the conventional water-quality parameters, and every 48 hours for measurements of nitrates and ammonium.

The turbidity sensor, with nephelometric turbidity units (NTUs), measured the intensity of transmitted light reduced by suspended solids. By calibrating these measurements to a formazine standard, total suspended solids (mg/l) could be estimated. The conductivity sensor measured the ability of the water to conduct electricity based upon the presence of charged particles in solution. Conductivity, measured in microSiemens (uS), is proportional to the amount of total dissolved solids (TDS) in the water column.

When an automated temperature correction is applied, TDS may be estimated (based upon a defined relation between uS and mg/l-TDS).

The sensor deployment strategy was based upon field survey observations, past historical records obtained from Harford County and APG Installation personnel, and guidance from Waterways Experiment Station. The water quality stations were deployed at the following five sites:

1) 100 m below the confluence of East and West Branch of Winters Run (WEW)
2) 200 m below Bear Cabin Branch (BCB)
3) in Winters Run (ATK)
4) Plum Tree Run (PTR) as it enters Atkisson Reservoir
5) immediately above Van Bibber Water Treatment Facility (VB).

4. RESULTS

4.1 OVERVIEW

Based on the results of field monitoring during the Spring runoff period, erosion (soil loss from the subcatchments) and water-quality (eutrophication) model-based simulations were conducted. The first subcatchment soil loss (sheet erosion) simulation targeted the April 15/16 storm period. During this period, a 2-inch, 4.5-hour rain event occurred with an average intensity of .44 inches/hr. A record of this event is shown in Figure 3. Field sensor observations indicate that this storm event contributed from 1500 to 5000 mg/l total suspended solids (TSS) (Figure 4a). The highest readings were exhibited at the sensor station above Van Bibber. The TSS model results (Figure 4b) compared favorably with the observed results, including the accompanying predictions in sediment deposition shown in Figure 4c. The large peak in deposition, exceeding 20,000 mg/l, is indicated at segment 51 — Atkisson dam. A smaller peak, 5000 mg/l, is evident at the Maryland Water Treatment Facility dam located at segment 39. It is interesting to note that a substantial amount of sediment appears to remain in suspension (in the water column) while the water is passing over the dam, and is subsequently deposited above Van Bibber. Evidence of this phenomenon is provided by the results of the field survey, which document the presence of a growing number of islands and sand bars at this location.

The second subcatchment soil loss (erosion) simulation focused on precipitation events that occurred during May 8 and 9. This recorded event, as shown in Figure 5, yielded 1.1 inches of rain during a 2.75-hour period with an average intensity of 0.40 inches/hr. As indicated in Figure 6a, this event contributed less than one-half the amount of TSS, from 500 to 2000 mg/l, observed in the April storm. Figure 6b shows close concurrence between observed and predicted TSS data. The amount of sediment deposition indicated in Figure 6c shows about a 50% reduction in contributions to sediment bedload as compared to the April simulation.

A water quality — eutrophication — simulation was conducted for the period May 4/5, During which several small rain events occurred (Figure 7a). The corresponding diurnal temperature variation, from 12 to over 20 degrees celsius, is charted in Figure 7b. This variation is also witnessed in the observed dissolved oxygen profiles in Figure 8. These profiles showed a significant dissolved oxygen sag at the Van Bibber sensor station after 2200 hrs. The dissolved oxygen profile from the Van Bibber sensor station for the entire monitoring period is shown in Figure 9. These data reflect repeated sags below 5.0 mg/l between April 18 and May 11. Previously recorded Harford County stormwater outfall data was used to calibrate the model with respect to the observed data. These data reflect substantial BOD and COD loads from the Festival of Belair and Constant Friendship Shopping Mall outfalls. Other stations reported dissolved oxygen values reflective of normal or near-saturation ranges.

With the exception of Plum Tree Run, the field stations reported approximately 80 mg/l Total Dissolved Solids (TDS) between rain events. However, measurements at Plum Tree Run indicated a twofold increase in TDS to approximately 160 mg/l. This indicates possible problems upstream including leaching from acknowledged sources such as Tollgate Landfill or septic tanks. Similarly, pH measurements for all reporting stations, except Plum Tree Run (which measured values below 6), yielded results in the 6 and 7.0 range.

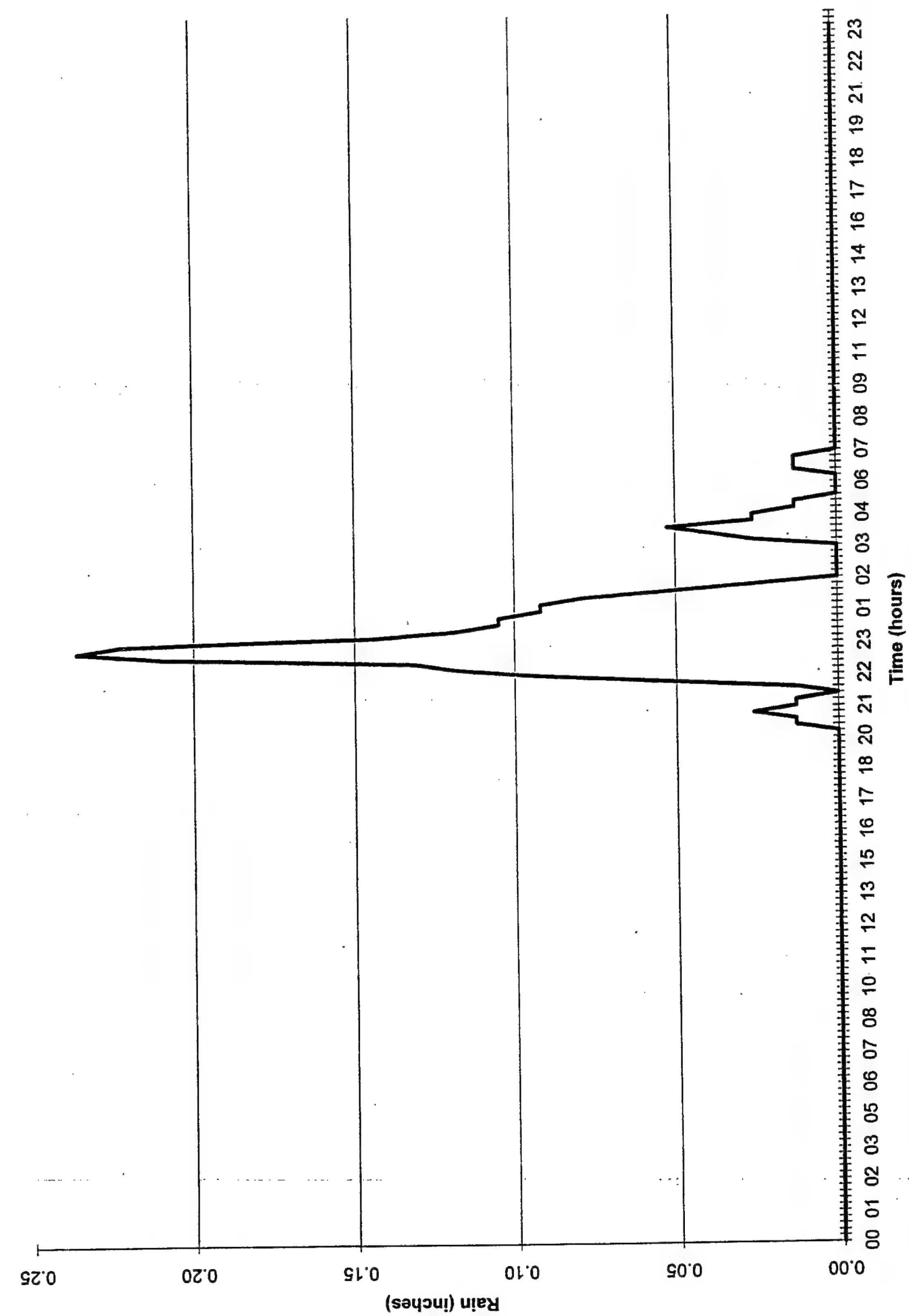

Figure 3. Remote Sensor Rain Event - April 15 and 16, 1996

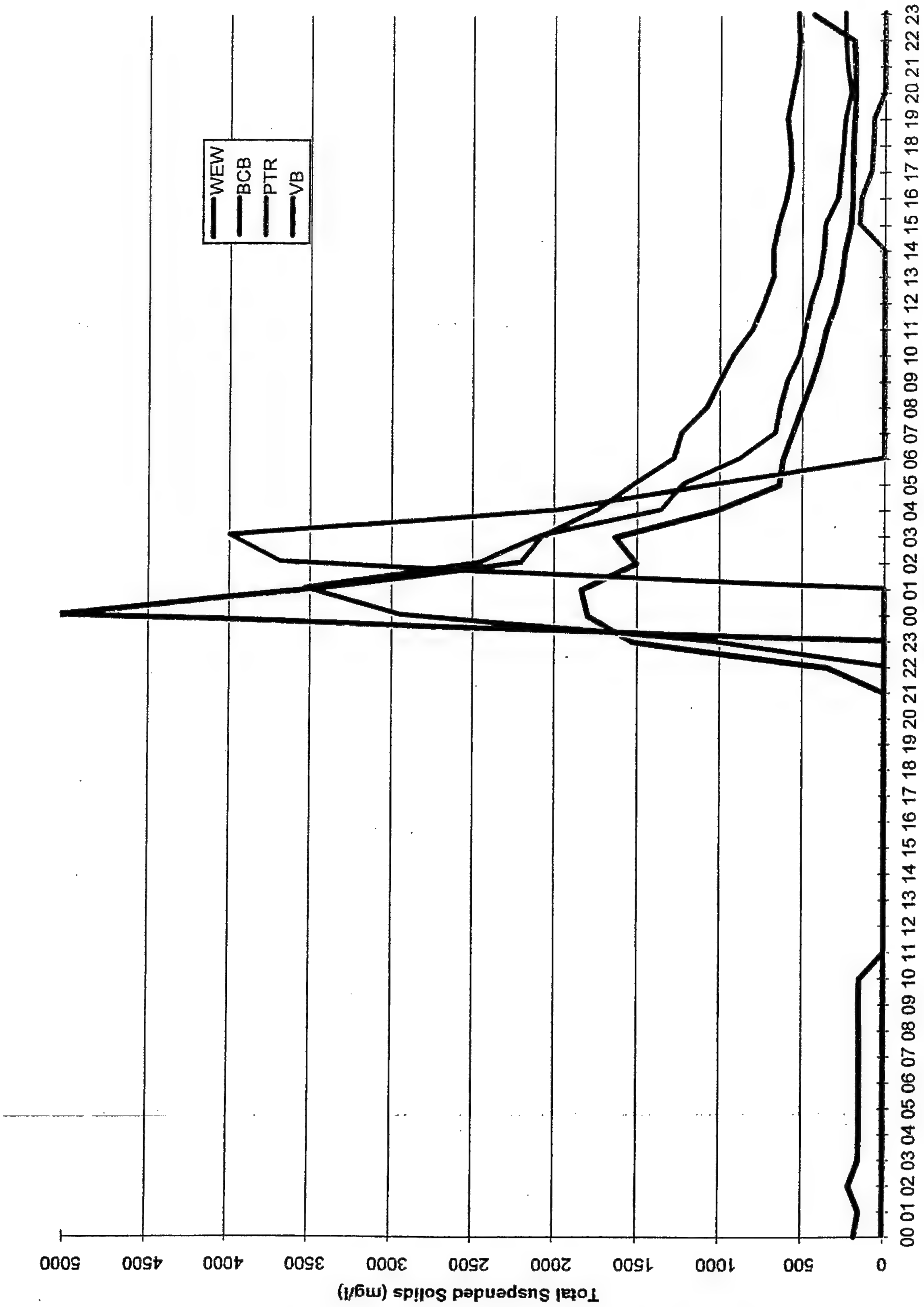

Figure 4a. Remote Sensor Measurement of Suspended Solids - April 15 and 16, 1996

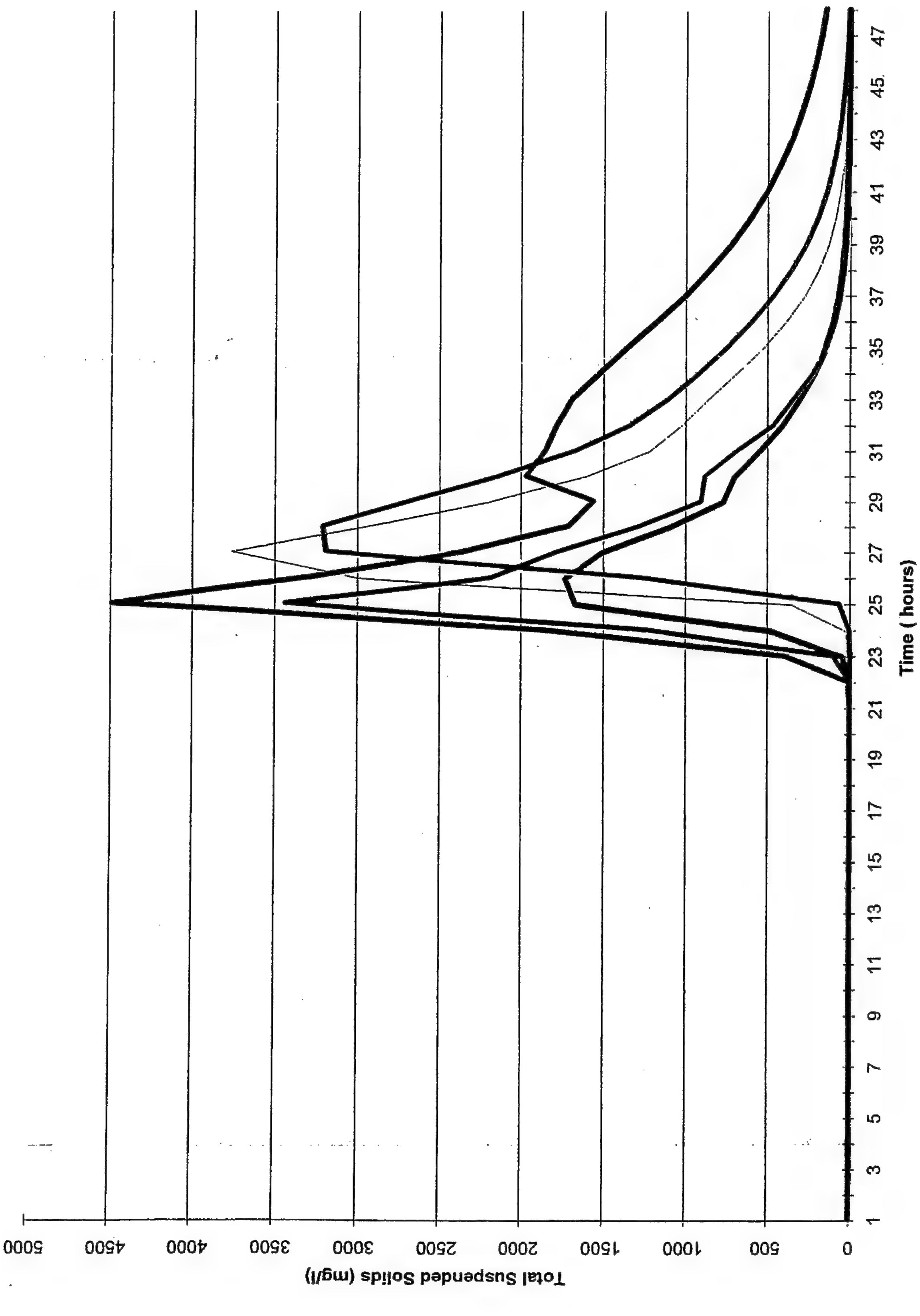

Figure 4b. Suspended Solids Model Estimate - April 15 and 16, 1996

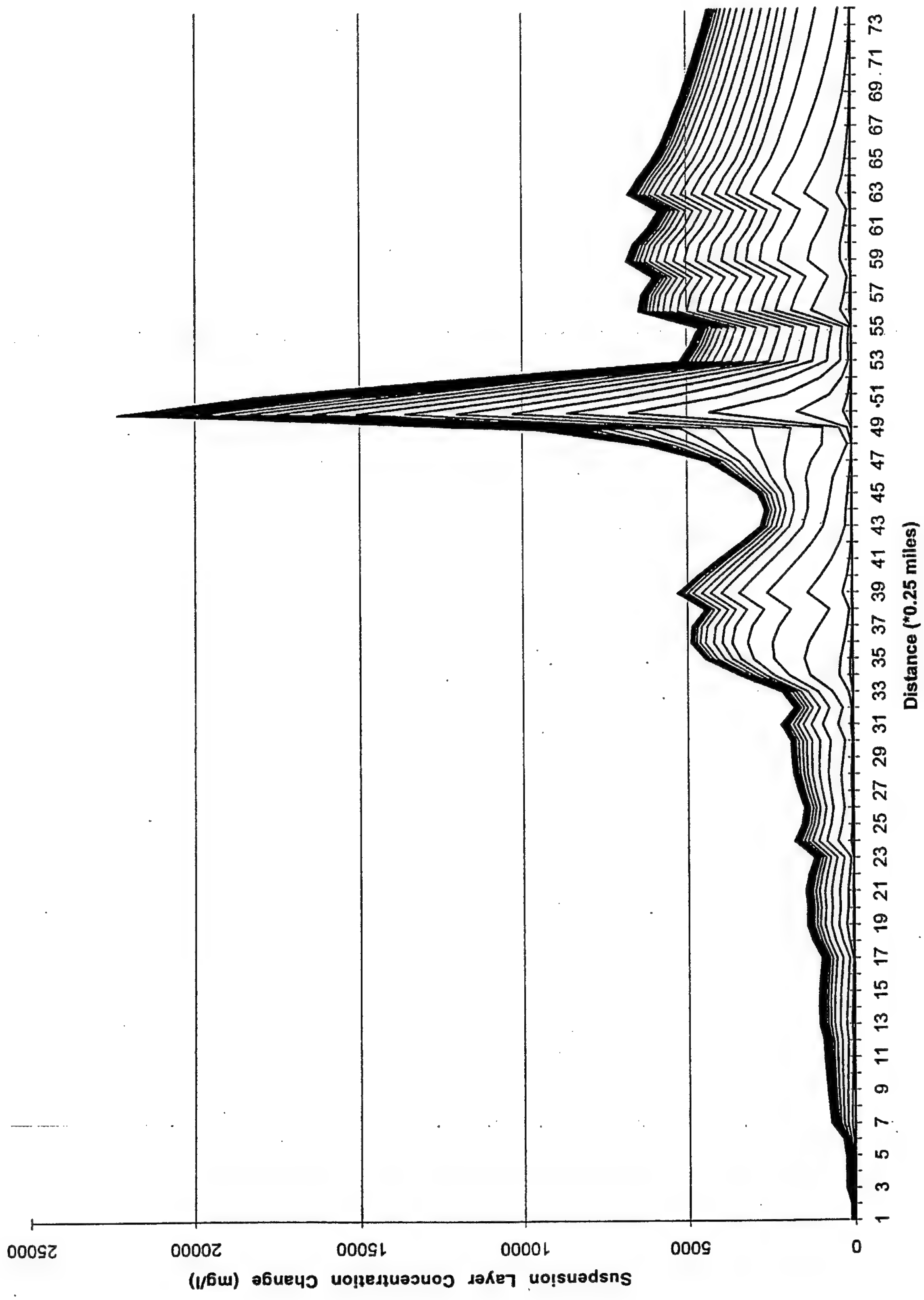

Figure 4c. Sediment Deposition Model - April 15 and 16, 1996

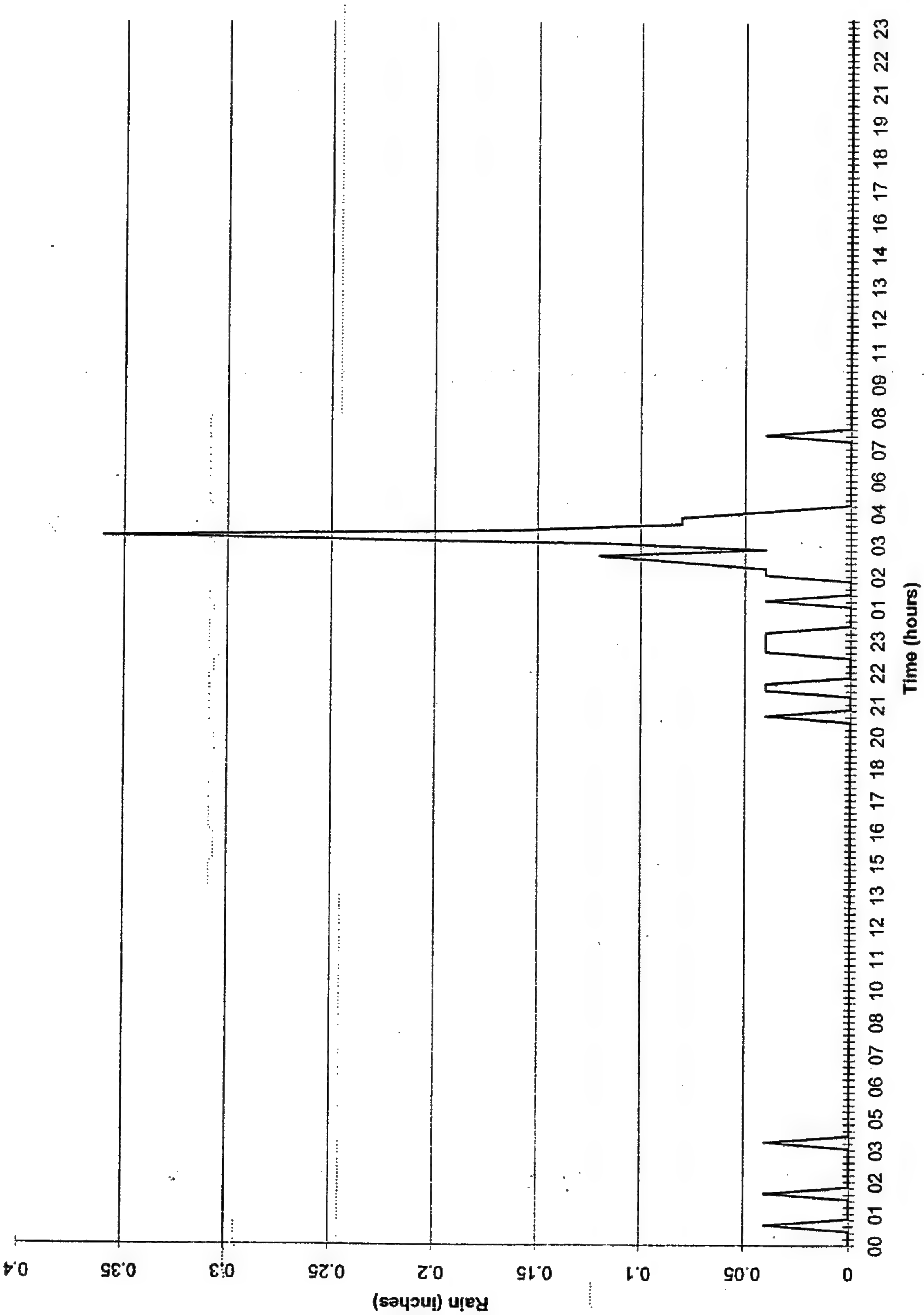

Figure 5. Remote Sensor Rain Event - May 8 and 9, 1996

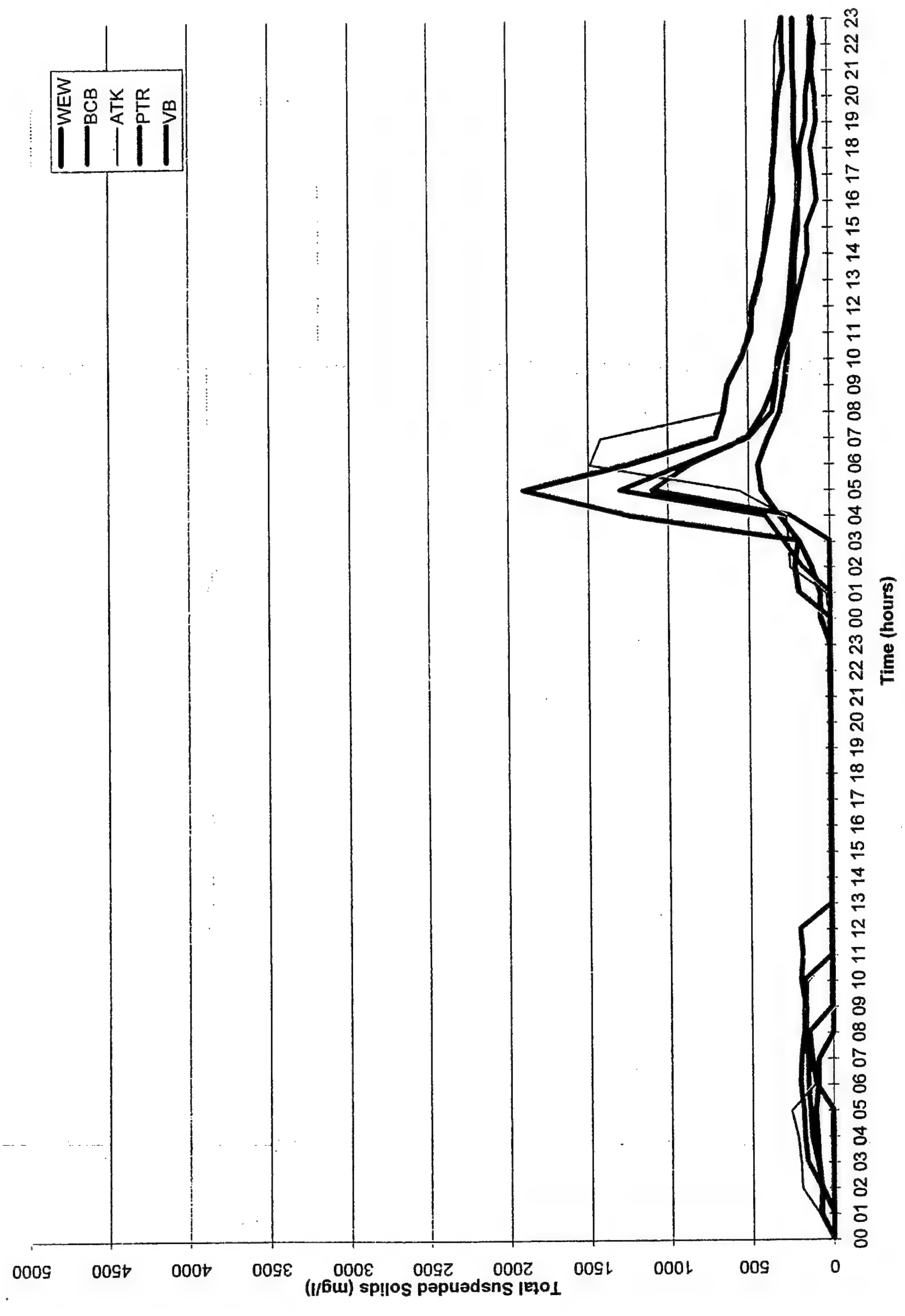

Figure 6a. Remote Sensor Measurement of Suspended Solids - May 8 and 9, 1996

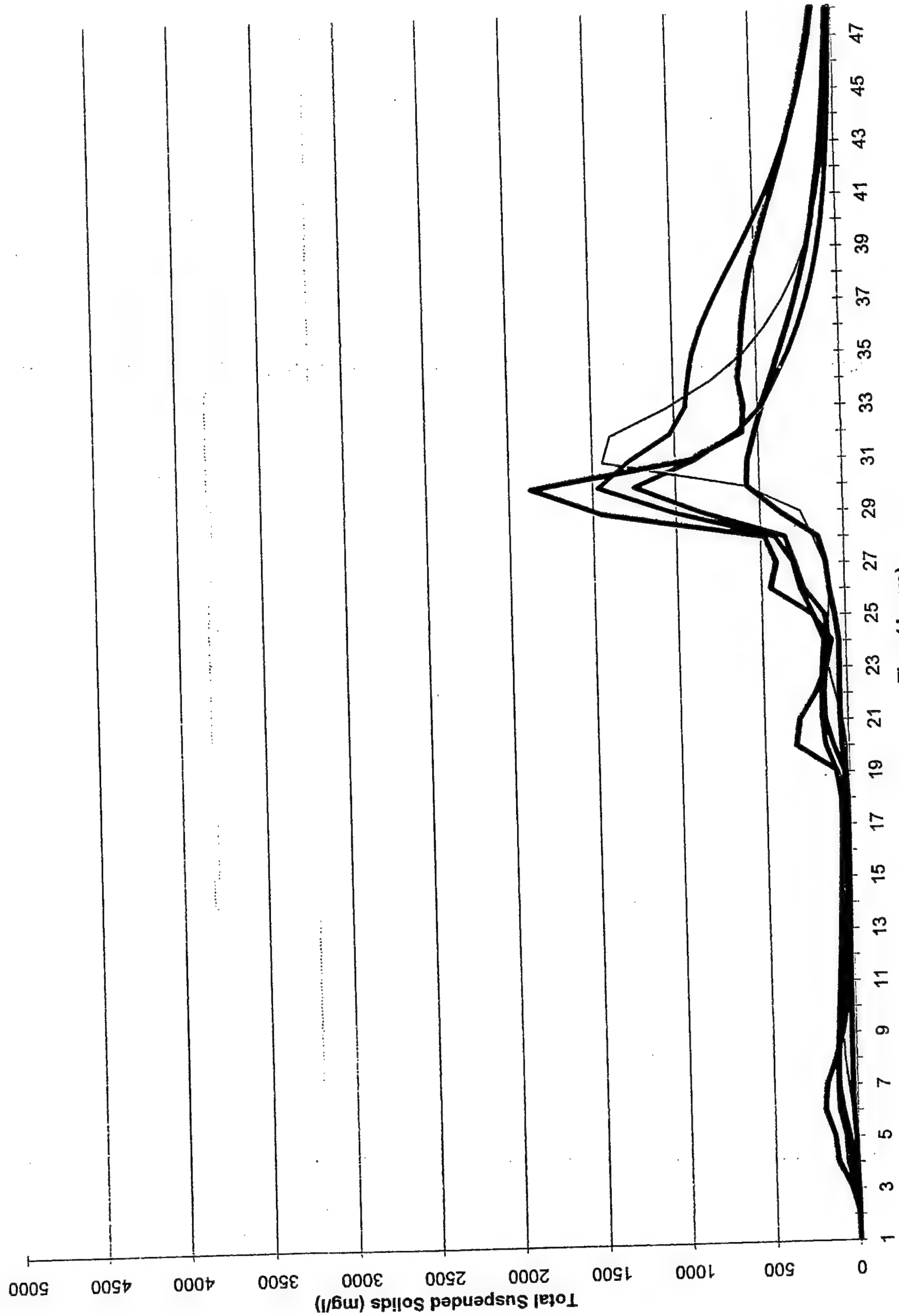

Figure 6b. Suspended Solids Model Estimate - May 8 and 9, 1996

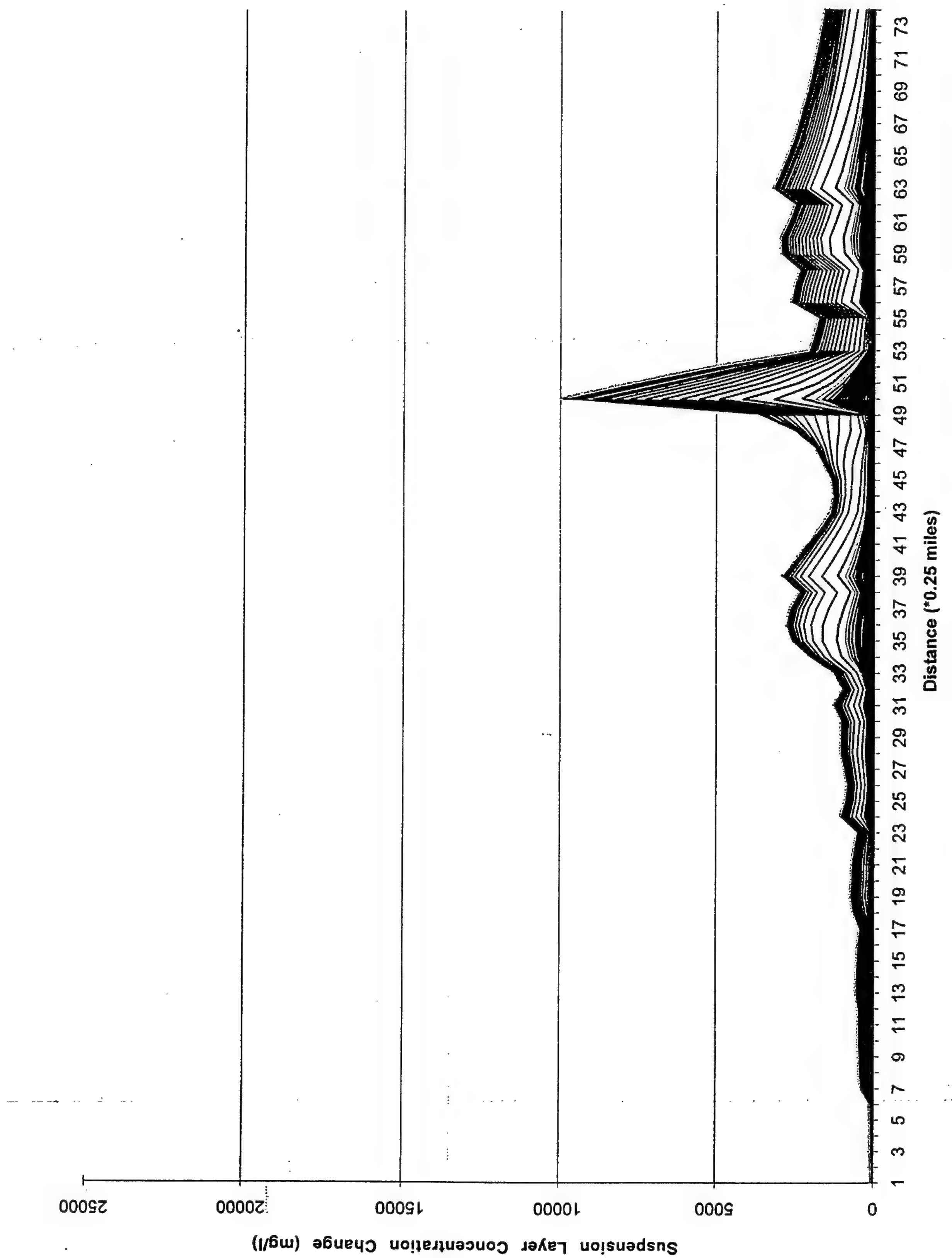

Figure 6c. Sediment Deposition Model - May 8 and 9, 1996

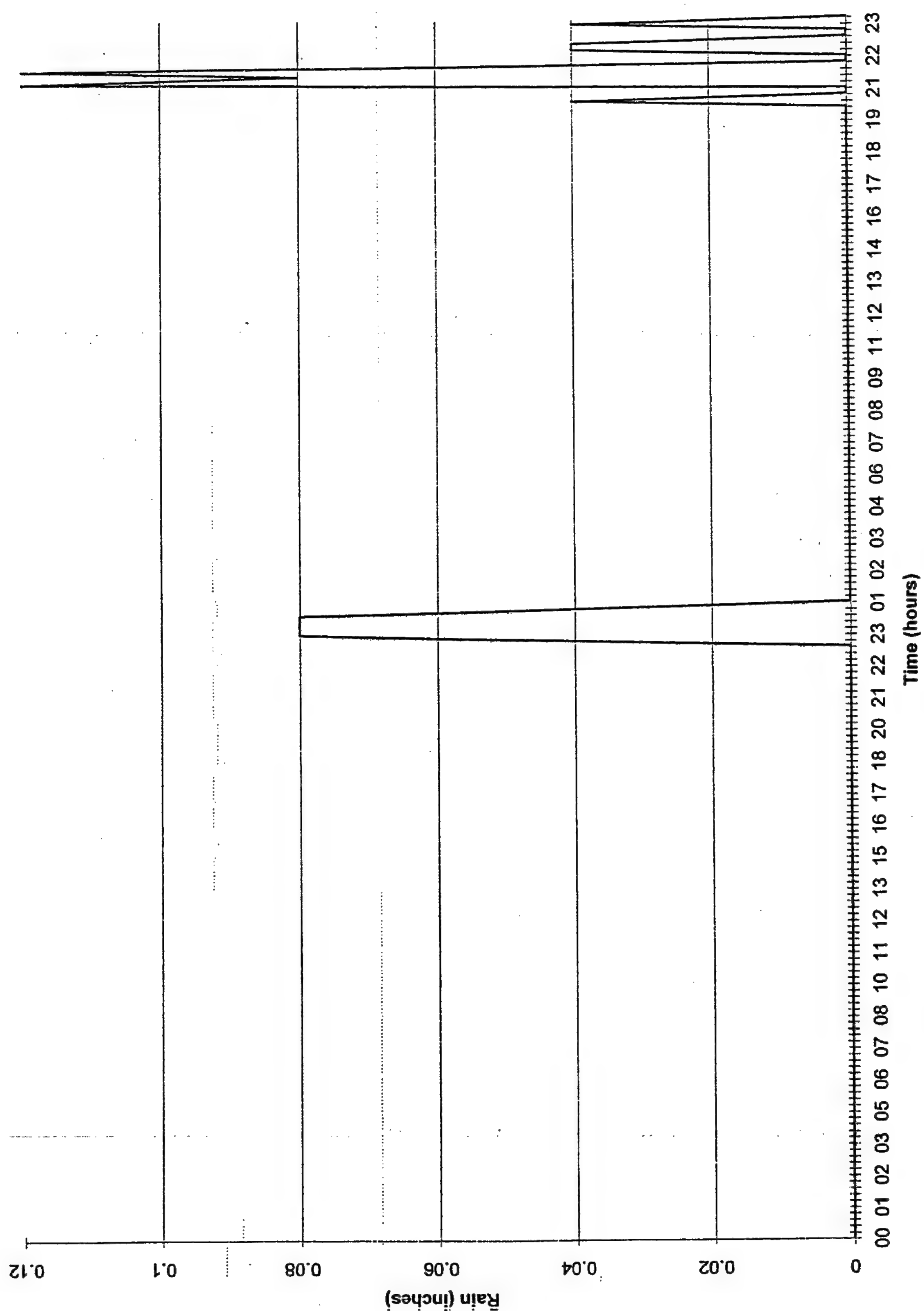

Figure 7a. Remote Sensor Rain Event - May 4 and 5, 1996

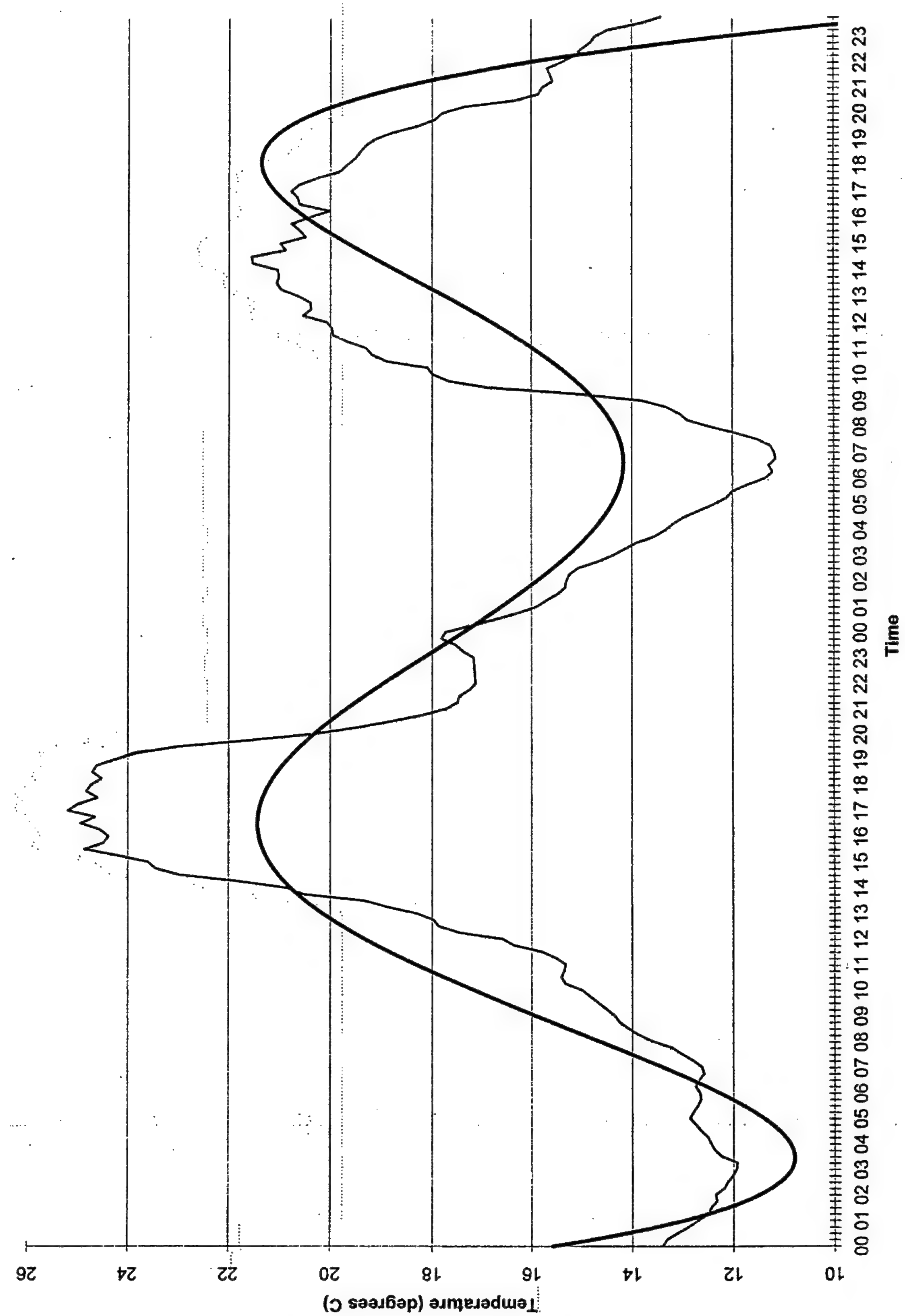

Figure 7b. Remote Sensor Ambient Temperature - May 4 and 5, 1996

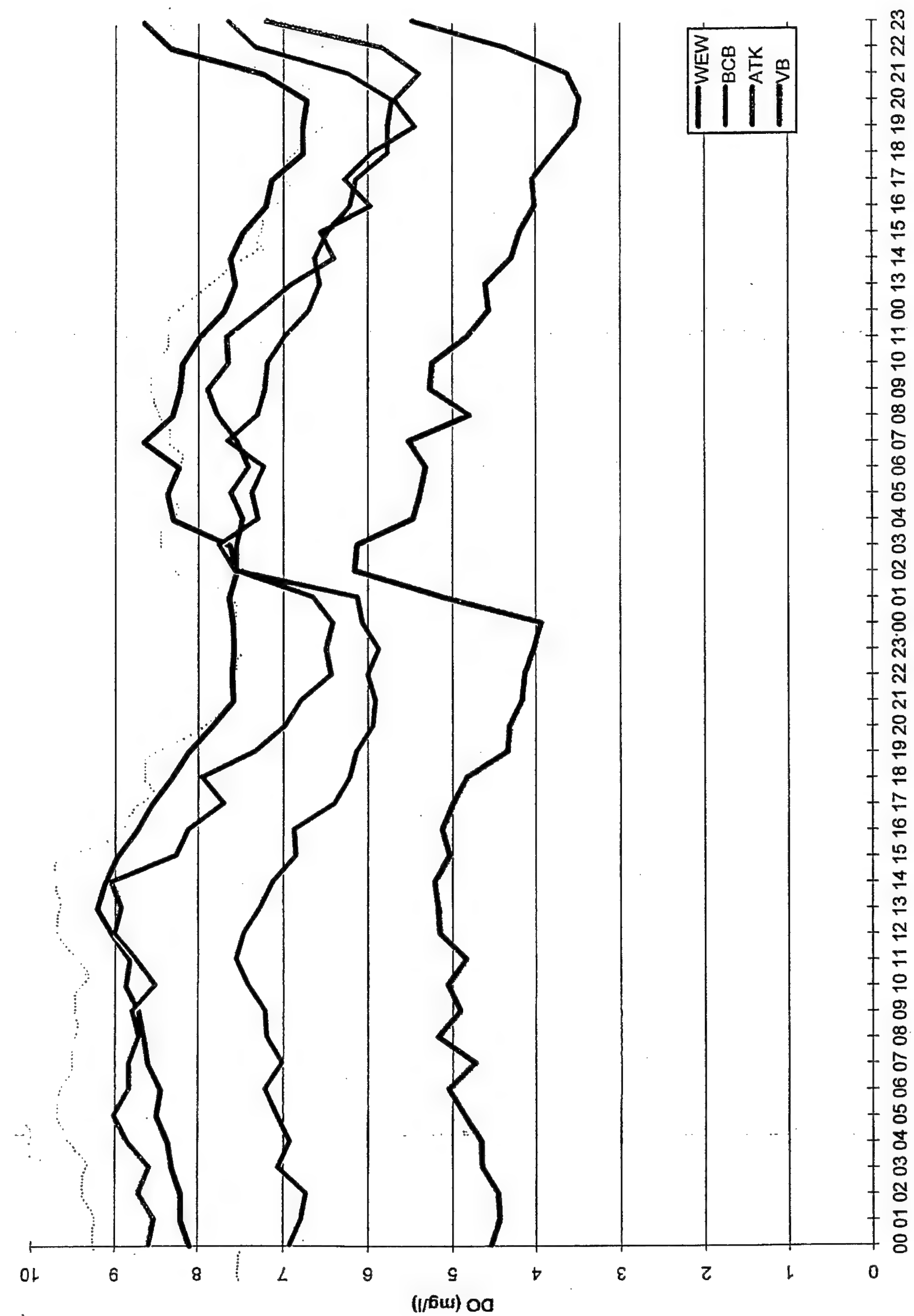

Figure 8a. Remote Sensor Measurement DO - May 4 and 5, 1996

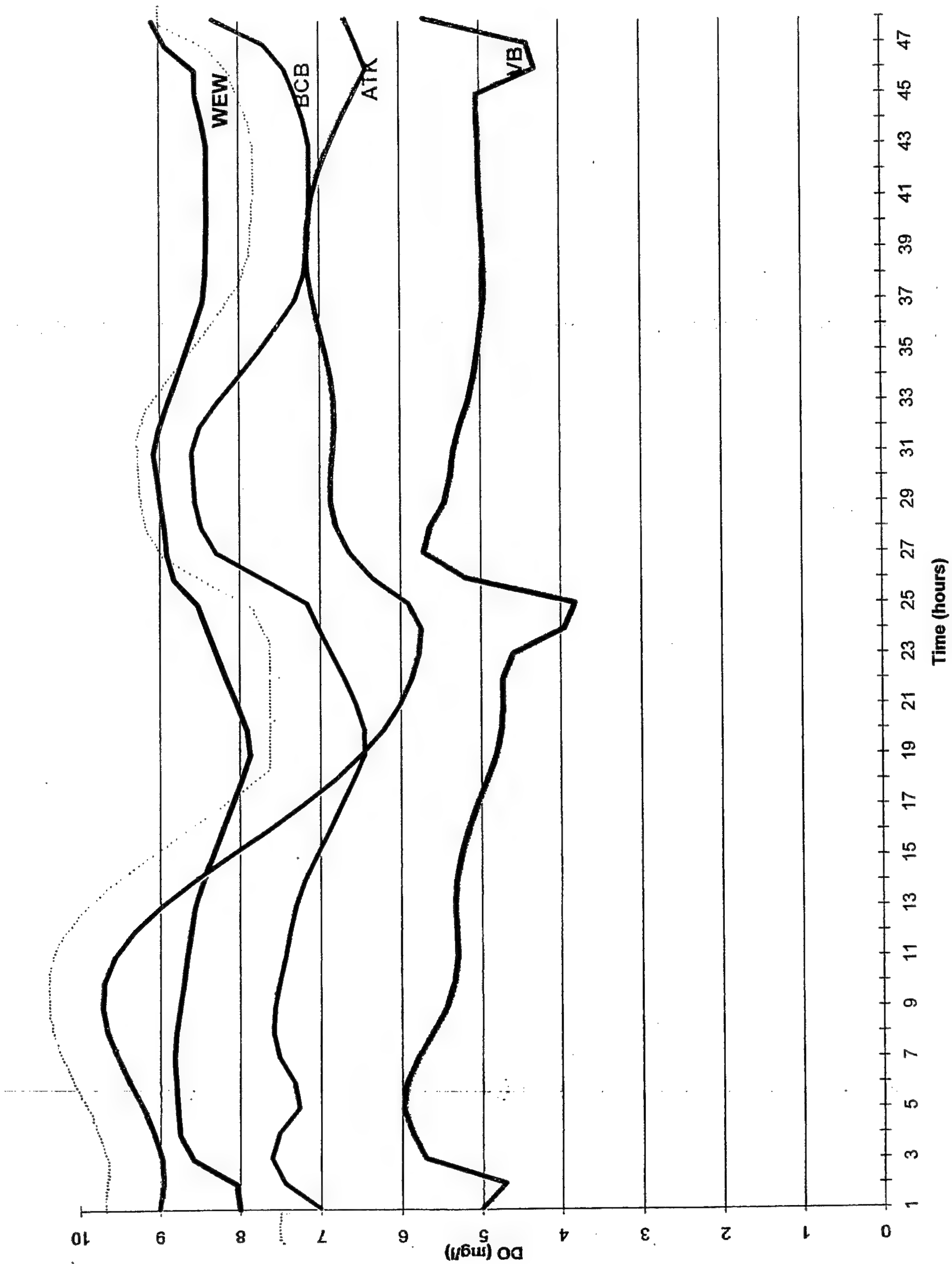

Figure 8b. DO Model Estimate - May 4 and 5, 1996

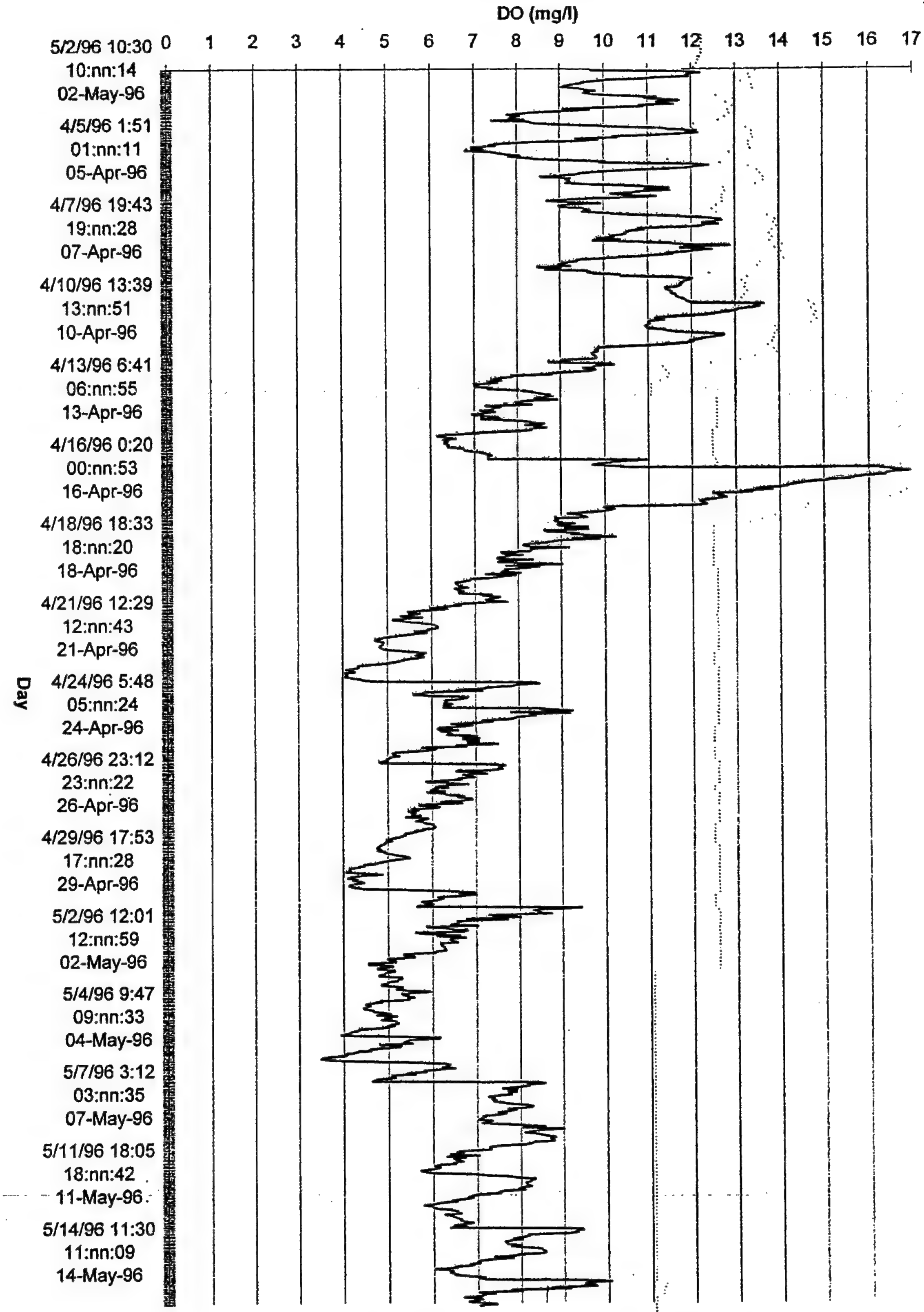

Figure 9. Remote Sensor Measurement DO - Van Bibber - April and May 1996

Simulation results from the water quality model output files were used for GIS visualization. Customized AVENUE scripts were used to facilitate model-based input to the GIS animation. Graphic examples of these temporal animations are shown in Figures 10a-10c. These graphics show results for sheet erosion at Hour 24, sedimentation at Hour 47, and water quality at Hour 26. Using this procedure, an integrated temporal and spatial analysis was conducted. Sheet erosion simulations were used to create the composite view of the Winters Run watershed depicted in Figure 11. This coverage indicates that the loadings from Bear Cabin Branch, Heavenly Waters, and Plum Tree Run tributaries contributed a substantial portion of the soil loss for this watershed. This graphic, with its accompanying legend, indicates that contributions from the agricultural areas (farm 1 and 2 landuse classes) tend to dominate the subcatchment sheet erosion process. The data also suggest that improved land and waste management practices for farming and neighboring undeveloped areas could help to curb effluent streams. Significant contributions from combined agricultural runoff and septage sources are demonstrated in the Plum Tree Run profile shown in Figure 12. While most of these nitrates are shown to deposit in the Atkisson reservoir, considerable amounts remain in suspension and are carried down to Van Bibber (as shown in Figure 13).

4.2 ESTIMATED CHANGES TO STORAGE VOLUMES

Based on an historical coverage from USEPA's RF3 reach file, the original (1942) water surface area for Atkisson Dam was determined to be 2.9×10^6 ft^2 or 66.6 acres. This area is outlined in figure 14. Inside this identified region, the colored border reflects deposition zones of the reservoir, with the highest rate occurring in the area adjacent to the orange border, and a lower rate occurring in the yellow regions. The blue-colored areas are zones of depression. A subsequent survey in 1980 estimated that the water surface area had been reduced to 49.7 acres. A revised calculation of water-surface-area from our GIS database yielded an estimate of 29.8 acres or 1.6×10^6 ft^2 — over 55% reduction in surface area. For purposes of estimating the relative decrease in the amount of storage volume at Atkisson reservoir, an original triangular bathymetry was used. Based on data from field surveys and aerial reconnaissance, the reservoir was segmented into two distinct regions. The northern portion of the reservoir, containing numerous sand bars and islands, has an average depth of 2 feet. In the southern portion, depths range from 1 foot to approximately 10 feet at the base of the dam. From these estimates, an average depth of 3.5 feet for the entire reservoir was assumed. The new volume is thus estimated to be 4.55×10^6 ft^3 — an estimated decrease of 89% of original storage capacity.

4.3 RUNOFF/DISCHARGE RELATIONSHIP

An analysis of basin lag time was conducted based upon the previously mentioned three model simulations. The difference in the center of mass of net rainfall and center of mass of runoff (peak flow rate) was determined to be between 10 and 12 hours. A runoff (rational) coefficient, C, which converts the average rainfall rate of a particular recurrence to a peak runoff intensity, was also estimated. Using the current landuse classification, particularly surface cover, a weighted average runoff coefficient of 0.33 was calculated based

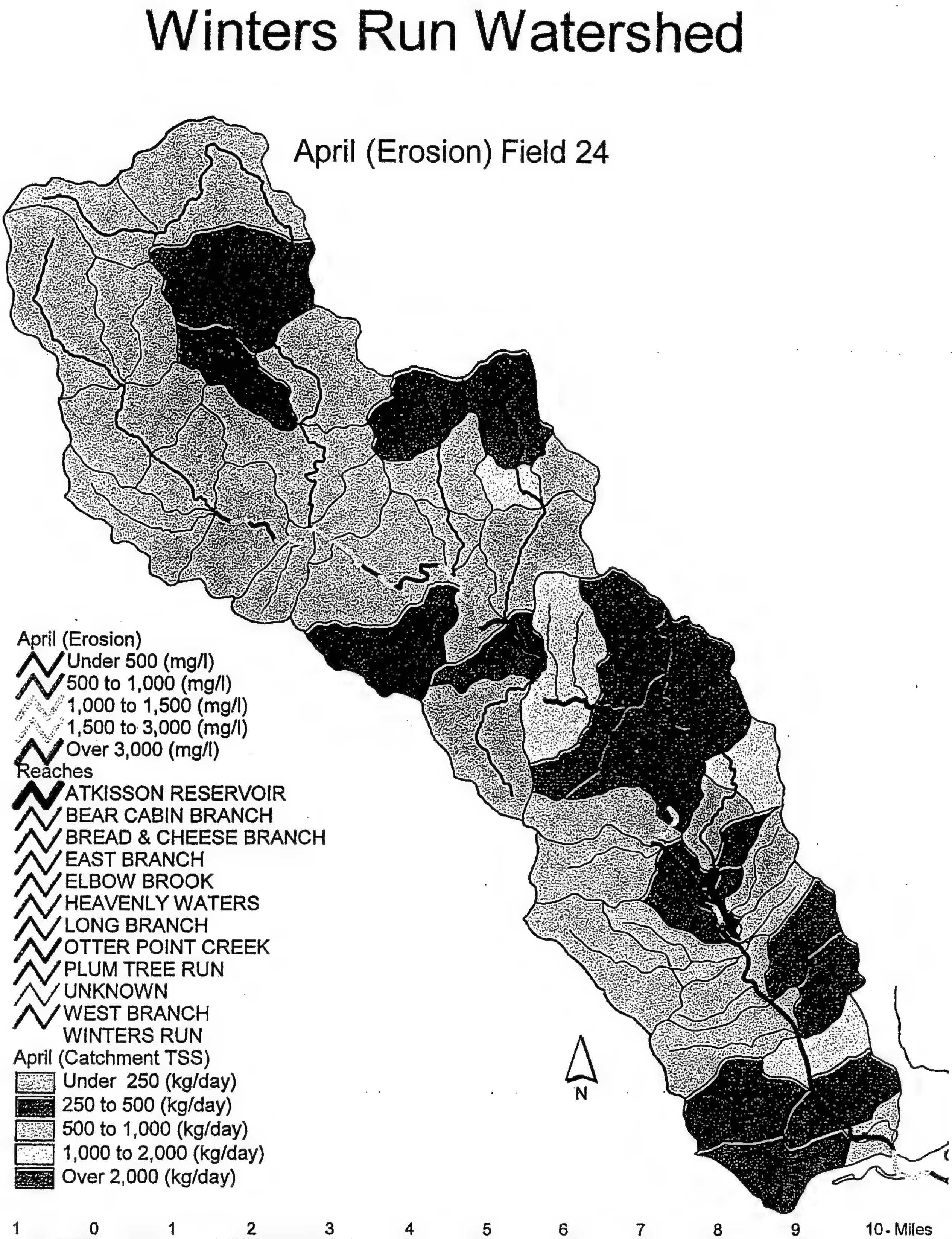

Figure 10a. Soil Loss (Erosion) at Hour 24 - April 1996

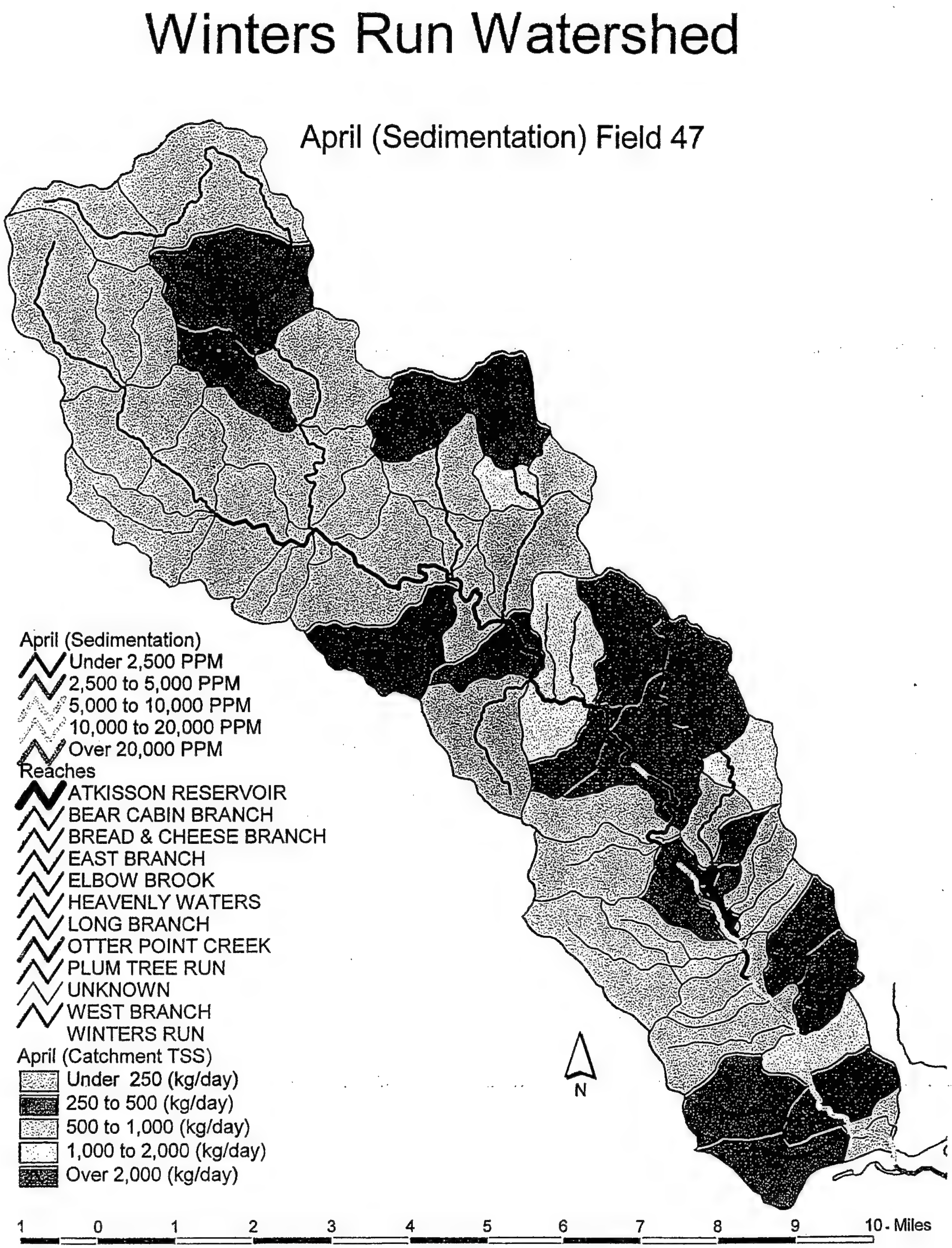

Figure 10b. Sedimentation at Hour 47 - April 1996

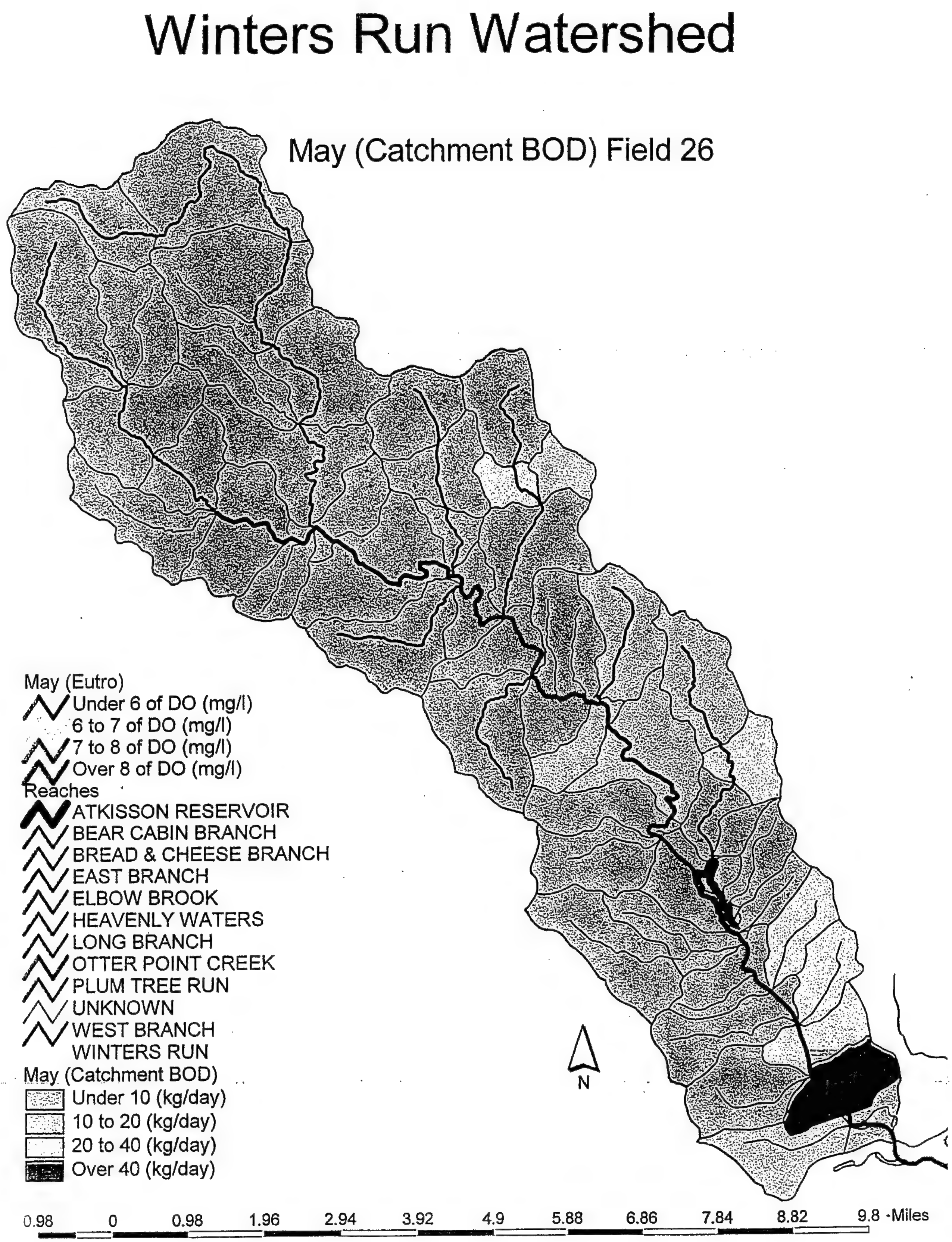

Figure 10c. Water Quality at Hour 26 - May 1996

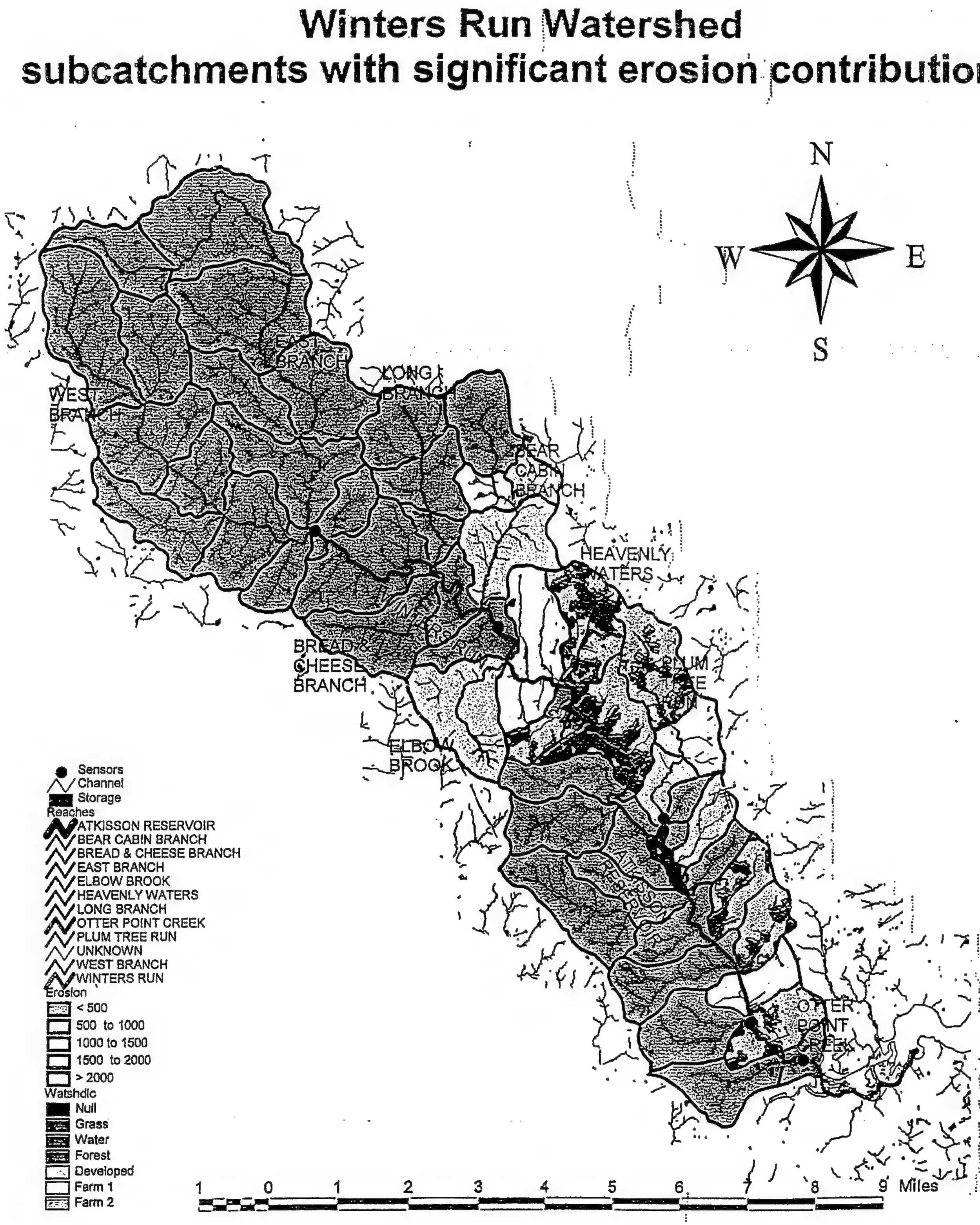

Figure 11. Composite of Erosion at Winters Run Watershed

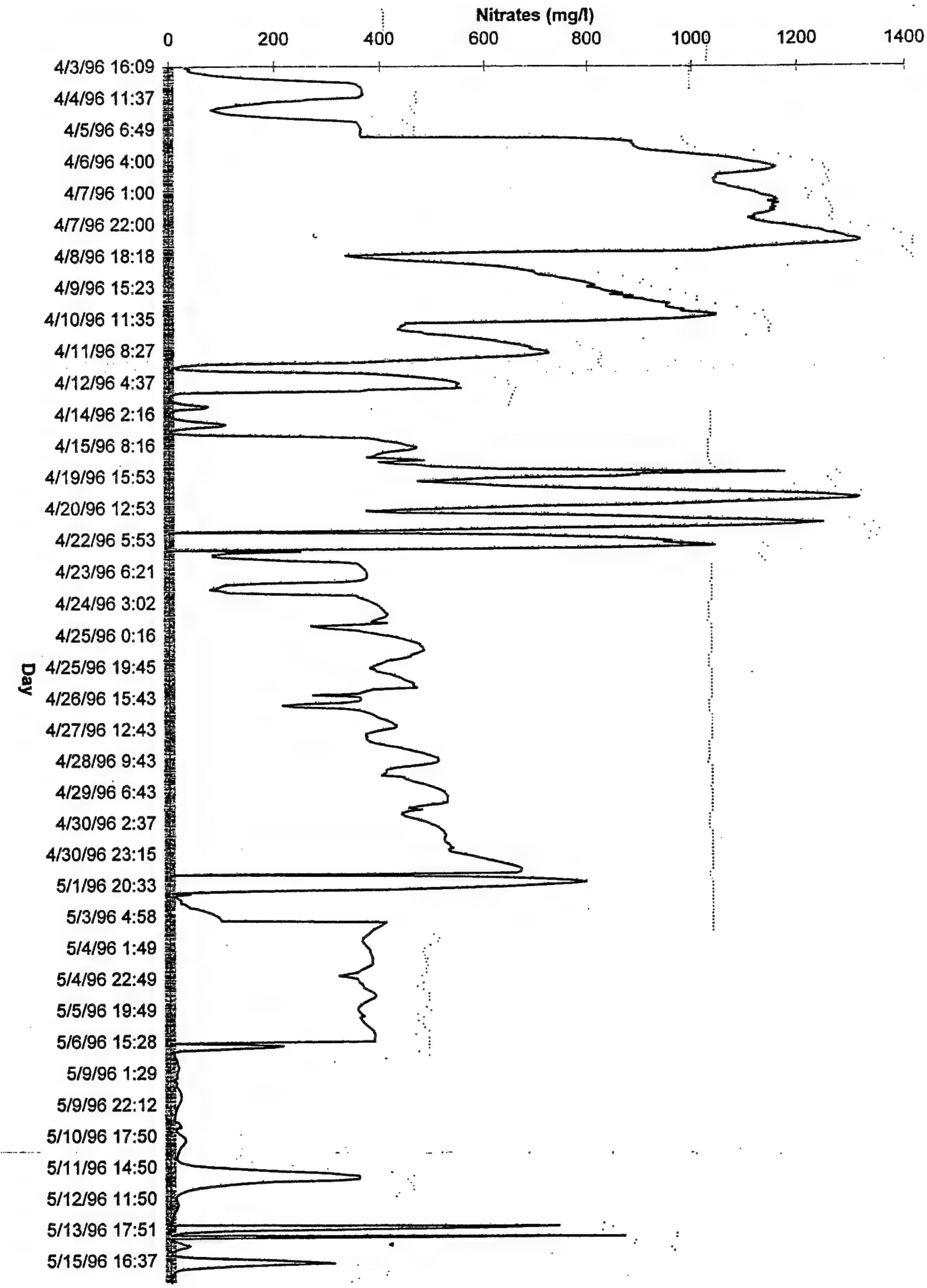

Figure 12. Remote Sensor Measurement of Nitrates - Plum Tree Run - April and May 1996

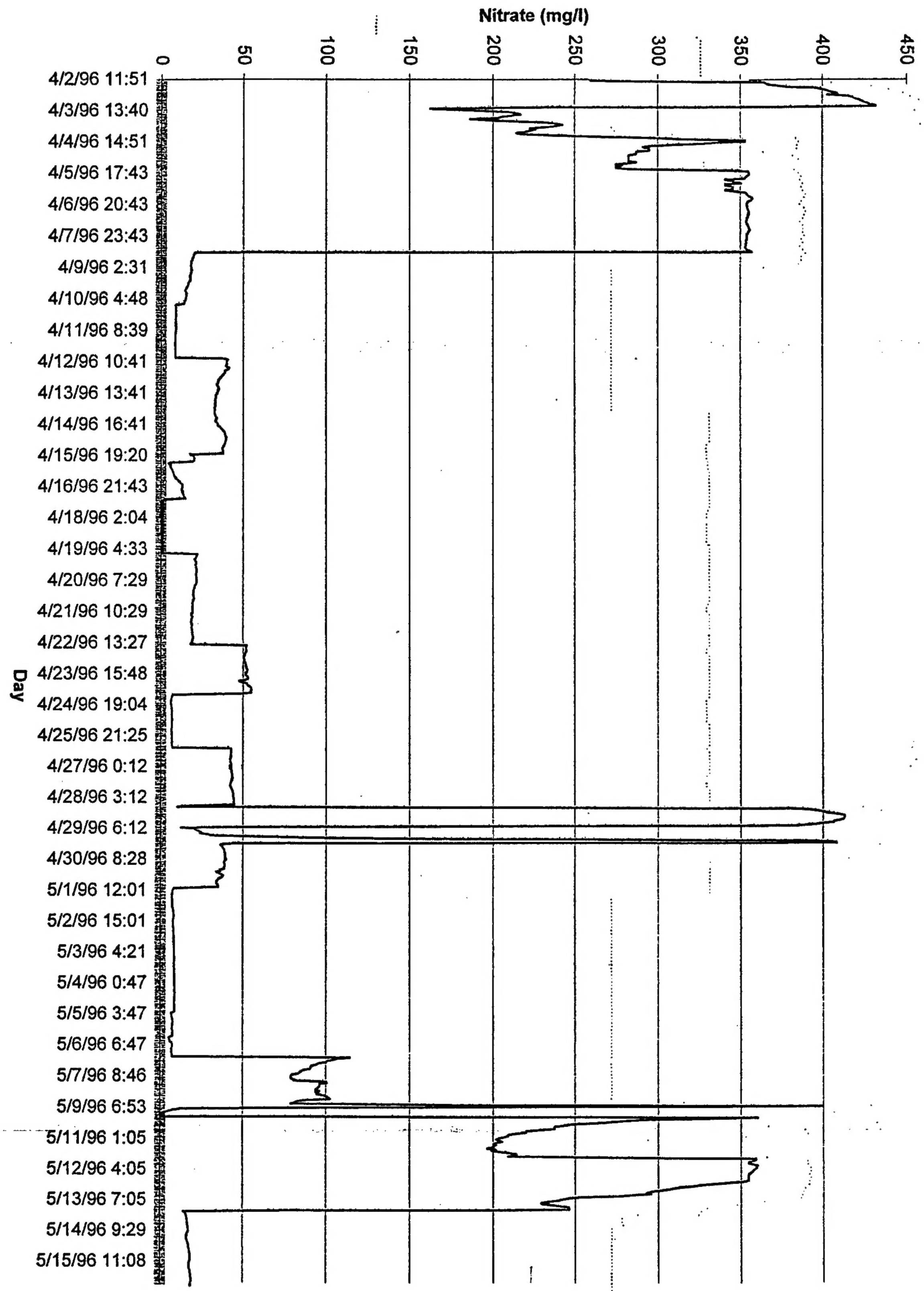

Figure 13. Remote Sensor Measurement of Nitrates - Van Bibber - April and May 1996

Figure 14. Area of Atkisson Dam

on the following average values: Forest = 0.2, Grassland = 0.35, Farm = 0.30, Urban/Developed = 0.6.
The time of concentration—defined as the time required for water to travel from the most remote portion of the watershed to its outlet—was calculated by the following empirical relation:

$$Tc = 0.03\,(1.1 - C)\,L^{0.5}\,S^{0.333}$$

where Tc is the time of concentration in hours, C is the runoff coefficient, L is the maximum length of overland flow in feet, and S is the slope in decimal percent of the longest overland flow path. A time of concentration of 11.2 hours was determined for the Winters Run watershed.

The rational method is defined by the relationship: Qp = CIA, (where Qp is the peak discharge, C = runoff coefficient (as mentioned above), I = rainfall intensity in inches per hour, and A = drainage area in acres), was employed. Based on observations of rain intensity during the Spring '96 runoff period, peak discharges at the watershed's outfall (Otter Point Creek) were predicted to be in excess of 5000 cfs. However, measured values at the sensor station above Van Bibber ranged from 1000 to 1500 cfs due to antecedent moisture conditions, depression storage, ground cover, and obstructions to flow (such as the dams at Maryland Water Treatment Works and Atkisson, and the weir at Van Bibber). As a matter for comparison, historical peak discharges (a measured flow of 7,600 cfs and stage height of 11.6 ft.) occurred during Hurricane Agnes.

5. SUMMARY

The prototype Environmental Monitoring and Management System (EMMS) provided effective data integration of raster, vector, GPS, and environmental contaminant data. Data were fused from federal, state, and county spatial digital sources, together with field-sampled physical and chemical data. This spatial database was subsequently interrogated to support time-series modeling and GIS simulations. Both spatial and temporal data fusion were necessary to define Winters Run watershed sediment transport dynamics. Quantitative impacts to Winters Run water quality from the Spring '96 wet-weather events were determined from integrative monitoring and modeling. Using image processing technology, impacts to landuse in the watershed were evaluated.

GIS-based modeling demonstrated that model input data sets could be generated in an automated fashion, and subsequently used for on-demand, iterative modeling calibration runs. In particular, due to the urbanizing nature of the watershed, surface runoff was calculated through the application of a Hortonian overland flow-based stormwater model. There was significant data reduction from the GIS database in order to derive approxmiately fourty input parameters based upon a specified soil type and land use for each of the individual subcatchments. Subsequently, generated surface runoff from each subcatchment was precisely mapped to a designated channel tributary for lateral flow

contributions. The hydrodynamics of Winters Run was captured in the development of data sets for over one-hundred geospatially-specified segments of the river. The visualization of results from receiving water quality model was linked to the previously determined river segmentation, as well as channel and lateral flows in order to conduct mass balances and determine eutrophication and soil loss impacts.

Use of a GIS-based, graphical user interface allowed the analyst to better interpret complex data. Time-series simulations allowed for the isolation of significant area nonpoint source contributors to soil loss. In particular, this included the identification of different farmland and septage contributions. Point sources included stormwater outfalls at two major shopping centers which provided significant loads below Atkisson dam. The combined influence of point and nonpoint sources for the Spring '96 runoff period were measured by the field water quality sensors. These data then were used for modeling purposes to allow for a baseline integrated assessment, and the potential development of a watershed total maximum daily load (TMDL).

Application of the Winters Run GIS database helped explain and predict the behavior of water, nutrients, pollutants, and soil erosion in the watershed. The soil loss data suggests that an evaluation needs to be made of the prevailing agricultural (farmland) erosion control practices. Furthermore, the highlighted rural subcatchments which provide contributions to Plum Tree Run need to be further examined for possible septage problems. Also, stormwater runoff needs to be more closely monitored for combined BOD and COD loadings. This database will serve to provide the foundation for further technical analysis required for an upcoming Environmental Impact Statement study concerning the Atkisson dam reclamation.